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A novel UWB wearable antenna

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Abstract

This paper presents a novel design of a wearable tapered slot Vivaldi antenna. The operating frequency of design is between 300MHz and 8 GHz. Jeans Cotton fabric with pure 100% Cotton has been used as the substrate with dielectric constant 1.56, while the radiating element patch and ground plane are made up of aluminum as conducting material. The analysis of the structures are carried out using CST Microwave Studio. Simulated results in terms of return loss, bandwidth, radiation pattern, current distribution as well as gain and efficiency are presented to validate the usefulness of the proposed design and different bending conditions are presented in this paper.

Keywords: UWB Antenna; Wearable antenna; Antenna Bending; Vivaldi antenna

Introduction

In the recent years, body-centric wireless communication becomes an important part of the fourth generation mobile communication systems (4G). In supporting the increasing interest in antennas and propagation research for body communication systems, the IEEE 802.15 standardization group has been established to standardize applications intended for on-body, off-body or in-body communication [1]. One of the dominant research topics in antennas for body-centric communications is wearable. A wearable antenna is meant to be a part of the clothing used for communication purposes, which includes tracking and navigation, mobile computing and public safety. Wearable antenna requirements for all modern application require light weight, low cost, almost maintenance-free and no installation [1,6-10].

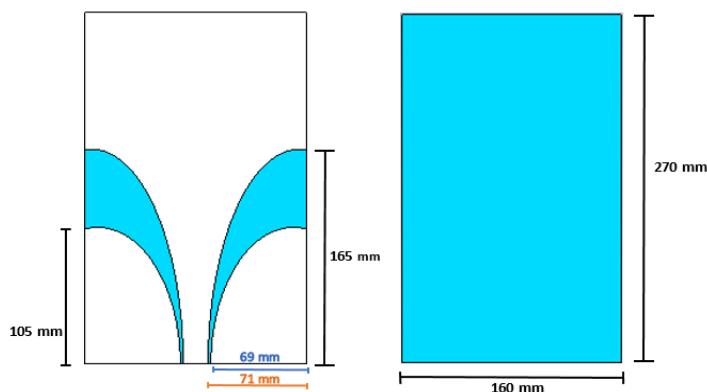


Fig 1: Dimension details of the proposed antenna

In this paper, the proposed design aims to improve the design of the antenna in [2], that can be integrated as part of garment and to be worn on the body, with the ability to extend wireless range that use ultra-wide band in addition to the low frequency. The rest of the paper is organized as follows: Section II presents antenna design and operation, whereas Section III discusses simulation results. After that in Section IV bending conditions of wearable antenna are discussed, While Section V illustrates the implementation and testing results for the antenna and finally, Section VI describes the conclusion.

Antenna Design and Operation

The proposed antenna (270mmX160mm) has a permittivity of (1.59) and thickness of 0.75mm for the substrate) and is fed through a 50Ω miniature adapter (SMA) connector.

As stated previously the dimensions of this antenna have been obtained using CST Microwave studio[3]. Fig. 1 shows the proposed antenna geometry. The arc of the two tapered slots is defined by the arc of an ellipse. The length of the semi-major and semi-minor axis of the smaller ellipse are (105) mm and (69) mm respectively and that for the bigger ellipse are (165) mm and (71) mm.

A prototype antenna was fabricated to verify the performance. Fig. 2 shows the proposed prototype antenna. Jeans Cotton fabric has been used as the substrate of the antenna, while the radiating element patch and ground plane are made from aluminum tape. However, using the copper tape instead of aluminum gives better results for the antenna.



Fig 2: Fabricated prototype.



Fig 3: Prototype antenna fabrication on a jeans shirt.

Simulation Results

A. Reflection Coefficient

Fig. 4 below represents the return loss of the proposed design.

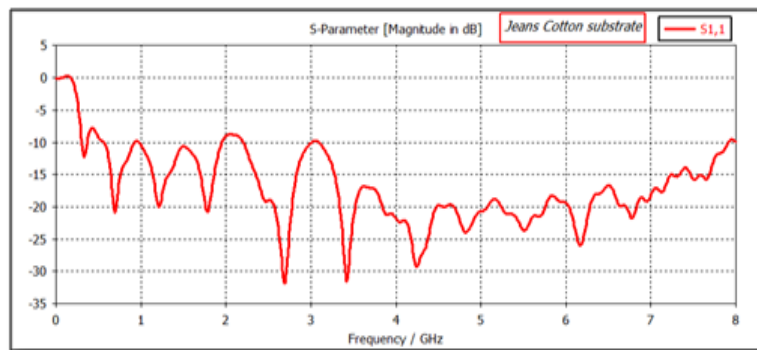
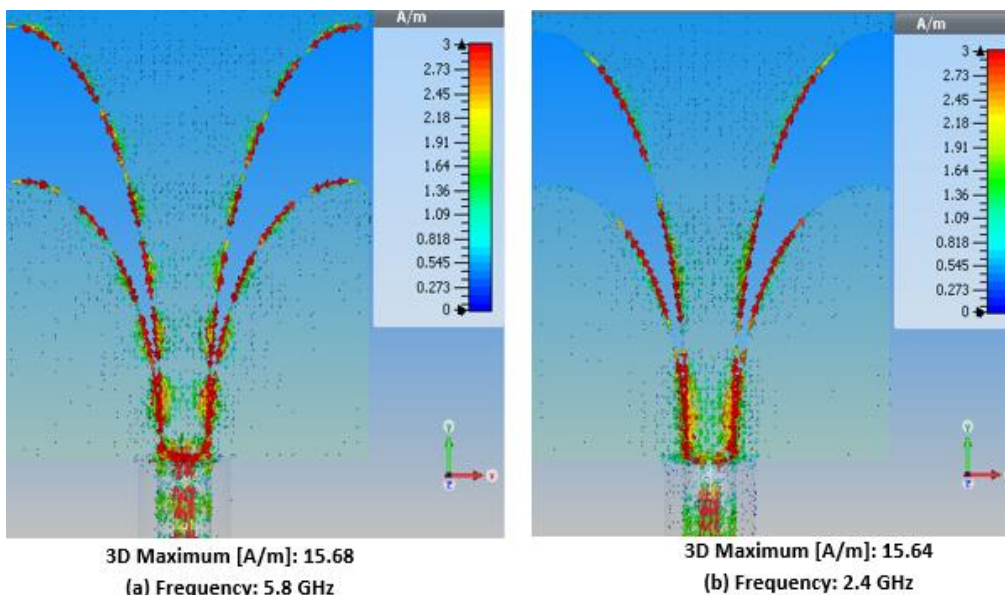


Fig 4: Simulated reflection coefficient of the proposed antenna design using Aluminum for conducting material

B. Surface current.

Fig. 5(a) and 6(b) show the simulated surface current distributions of the proposed antenna design at different frequencies.



3D Maximum [A/m]: 15.68
(a) Frequency: 5.8 GHz

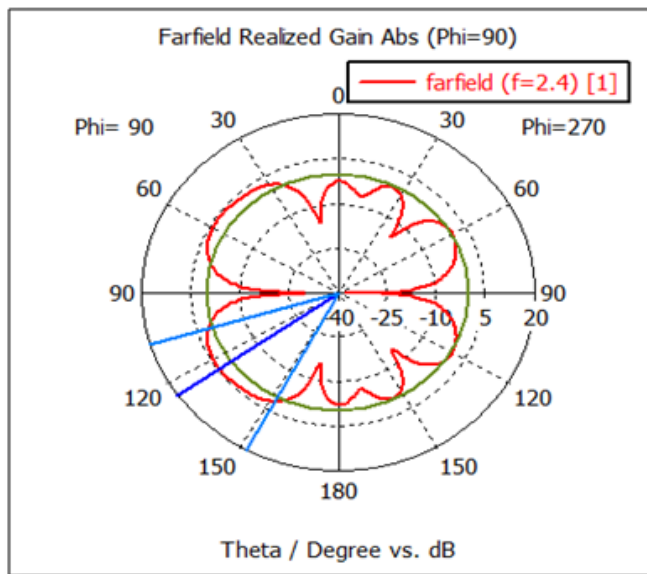
3D Maximum [A/m]: 15.64
(b) Frequency: 2.4 GHz

Fig 5: Simulated current distribution of the antenna at (a) 5.8 GHz and (b) 2.4 GHz.

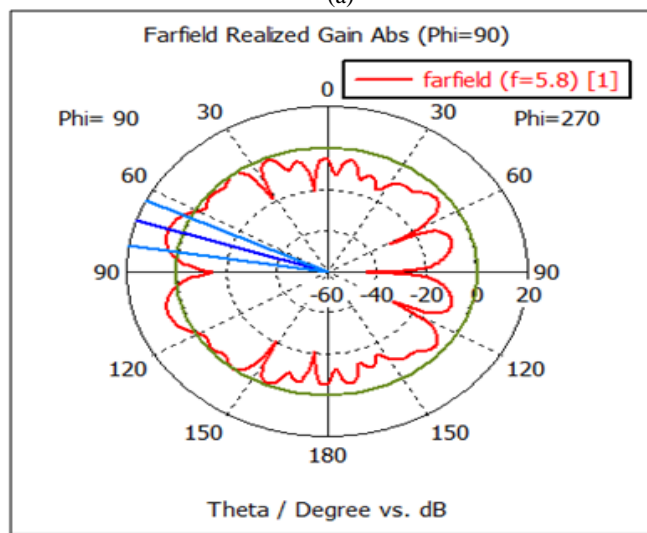
C. Radiation Patterns and Gain.

The antenna pattern describes the relative strength of the radiated field in multiple directions from the antenna. It includes both reception and transmission pattern. 2D radiation patterns (polar) in free space at different

frequencies when using Jeans Cotton textiles for substrate and Aluminum for the conductive material of the proposed antenna are shown in the Figures 6(a) and 6(b). The antenna gain ranges from 1-10 dB as shown in Fig. 7 which can be considered as good results.



(a)



(b)

Fig 6: Far field polar plot (2D) on free space at Frequency of (a) 2.4 GHz, (b) 5.8 GHz.

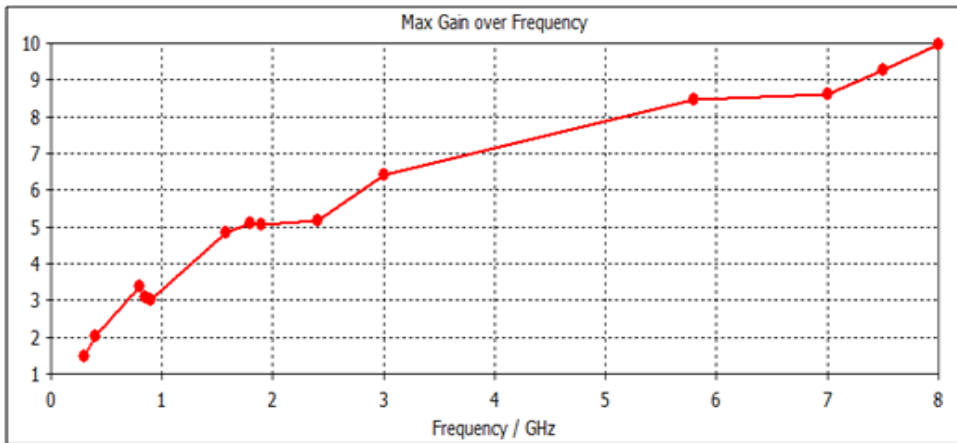


Fig 7: Measured gains vs. frequency of the proposed antenna in free space.

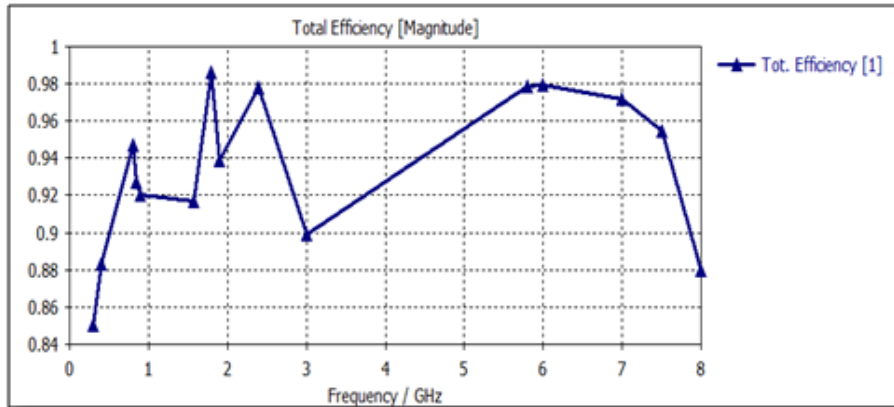


Fig 8: Simulated total efficiency in free space.

D. Efficiency.

Fig. 8 shows the measured total efficiency when the antenna is in free space. Total efficiency results usually give better indication than return loss results to highlight the filtering performance of the antenna; this is because the antenna total efficiency not only accounts for the input mismatch of the antenna but also accounts for the ohmic losses in the antenna [4, 5].

Bending of Wearable Antenna

In wearable systems, It is very difficult to keep the antenna flat all the time especially when the antenna is made of textile materials. Moreover, the wearable antenna bends continuously due to the human body movements and to ensure the antenna performance in real life applications is up to mark, especially when the antenna is applied to rounded parts of the body, such as the torso, it becomes necessary to investigate the antenna’s performance characteristics under different bending conditions. Based on the analysis, the proposed design have been tested under severe conditions to examine its ability to keep its operating bandwidth as desirable, the antenna have been bent with different angles as shown in Fig. 9.

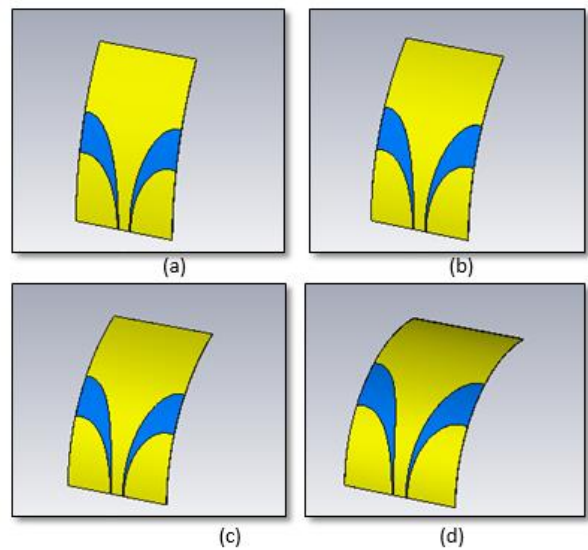


Fig 9: Simulation bending of antenna with four different angles (a) bend of 30 degree, (b) bend of 45 degree, (c) bend of 60 degree, (d) bend of 90 degree.

Fig. 10 illustrates the measured results of the return loss when different bending situations are applied to the proposed antenna, S11 parameter almost still the same, no major differences occur. Therefore, the antenna will be able to operate within the desired frequency range. The bending conditions were differentiated using degrees and when we increase the angle degree, the antenna will be bent more.

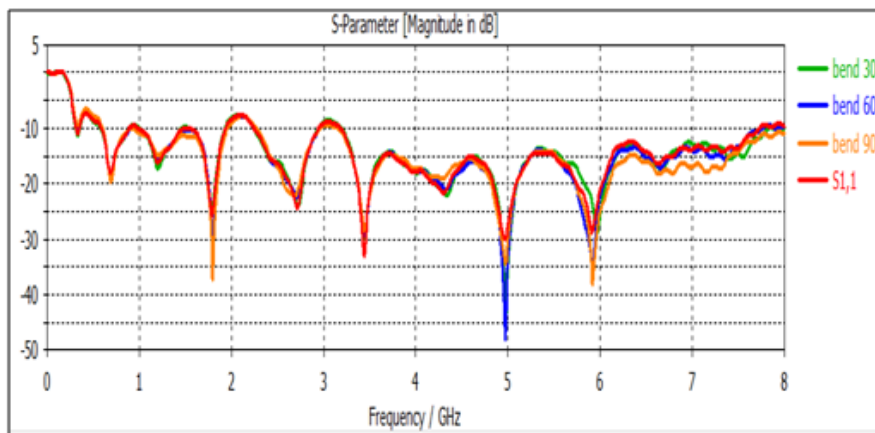


Fig 10: Reflection coefficient of different bending angles.

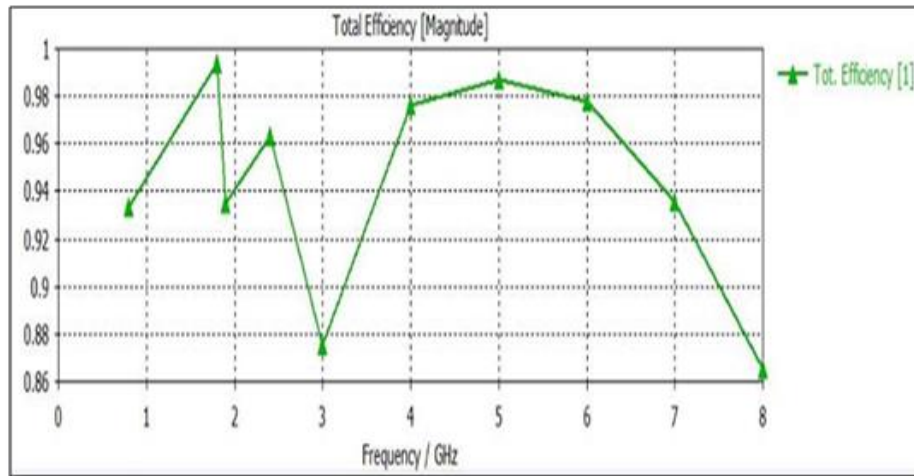


Fig 11: Simulated total efficiency of bent antenna.

Implementation

The antenna is tested by using a router for Wi-Fi signals and it has a good result as the connection was valid and it transmitted for approx. 15 meters with different movement and bending positions. To measure the signal strength on the receiver (a mobile in this case), an application which is Wi-Fi analyzer for android phones is used. This application

present the signal strength in different ways such as charts or a specific values of the strength measured in dBm to show the less crowded channels and networks available. Signal strength values obtained in dBm at the same distance, for the router original antenna was [-38dBm] and for the proposed antenna was approx. [-15dBm].



Fig 12: Connection between the antenna prototype and the router device.

Conclusion

A UWB and UHF planar and wearable antenna design using a Vivaldi antenna has been proposed. The antenna -6dB bandwidth ranges from 200 MHz up to 8 GHz. The antenna has stable radiation patterns, good gain and efficiency. The antenna has been used to receive 2.4 GHz Wi-Fi signals. The antenna can be easily integrated on wearable clothes and can be used for both civil and defense applications.

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